CLAIMS

What is claimed is:

1. A method of controlling removal rate uniformity during an electropolishing process in integrated circuit fabrication on a wafer, the method comprising:

applying a stream of electrolyte to the wafer using a nozzle positioned adjacent to the wafer with a gap between the nozzle and the wafer; and

adjusting the gap between the nozzle and the wafer to adjust the removal rate profile of the stream of electrolyte applied by the nozzle.

2. The method of claim 1, wherein, when the gap is less than a diameter of the stream of electrolyte, the removal rate profile of the stream of electrolyte has a concave shape; and wherein, when the gap is greater than the diameter of the stream of electrolyte, the removal rate profile of the stream of electrolyte has a convex shape.

3. The method of claim 1, wherein the stream of electrolyte is applied to different radial locations on the wafer, and wherein the gap between the nozzle and the wafer is adjusted based on the radial location of the stream of electrolyte on the wafer.

4. The method of claim 3, wherein the gap is greater when the stream of electrolyte is applied to a radial location closer to the edge of the wafer than when the stream of electrolyte is applied to a radial location closer to the center of the wafer.

5. The method of claim 1, wherein the stream of electrolyte is applied from the center of the wafer toward the edge of the wafer, and wherein the gap between the nozzle and the wafer is increased as the stream of electrolyte is applied from the center of the wafer toward the edge of the wafer.

6. The method of claim 1, wherein the stream of electrolyte is applied from the edge of the wafer toward the center of the wafer, and wherein the gap between the nozzle and the wafer is decreased as the stream of electrolyte is applied from the edge of the wafer toward the center of the wafer.

7. A system for controlling removal rate uniformity during an electropolishing process in integrated circuit fabrication on a wafer, the system comprising:

a wafer chuck configured to hold the wafer during the electropolishing process; and

a nozzle configured to apply a stream of electrolyte to the wafer held by the wafer chuck, wherein the nozzle is positioned adjacent to the wafer with a gap between the nozzle and the wafer,

wherein the gap between the nozzle and the wafer is adjusted to adjust the removal rate profile of the stream of electrolyte applied by the nozzle.

8. A method of controlling removal rate uniformity during an electropolishing process of in integrated circuit fabrication on a wafer, the method comprising:

applying a stream of electrolyte to the wafer using a nozzle positioned adjacent to the wafer, wherein the nozzle includes a diffuser positioned within the nozzle; and

adjusting the position of the diffuser within the nozzle to adjust the removal rate profile of the stream of electrolyte applied by the nozzle.

9. The method of claim 8, wherein, when a distance between the diffuser and the wafer is less than a diameter of the stream of electrolyte, the removal rate profile of the stream of electrolyte has a convex shape; and wherein, when the distance is greater than the diameter of the stream of electrolyte, the removal rate profile of the stream of electrolyte has a concave shape.

10. The method of claim 8, wherein the stream of electrolyte is applied to different radial locations on the wafer, and wherein the position of the diffuser within the nozzle is adjusted based on the radial location of the stream of electrolyte on the wafer.

11. The method of claim 10, wherein, the diffuser is positioned within the nozzle with a distance between the diffuser and the wafer that is greater when the stream of electrolyte is applied to a radial location closer to the edge of the wafer than when the stream of electrolyte is applied to a radial location closer to the center of the wafer.

12. The method of claim 8, wherein the stream of electrolyte is applied from the center of the wafer toward the edge of the wafer, and wherein the diffuser is lowered within the nozzle as the stream of electrolyte is applied from the center of the wafer toward the edge of the wafer.

13. The method of claim 8, wherein the stream of electrolyte is applied from the edge of the wafer toward the center of the wafer, and wherein the diffuser is raised within the nozzle as the stream of electrolyte is applied from the edge of the wafer toward the center of the wafer.

14. A system for controlling removal rate uniformity during an electropolishing process in integrated circuit fabrication on a wafer, the system comprising:

a wafer chuck configured to hold the wafer during the electropolishing process;

a nozzle configured to apply a stream of electrolyte to the wafer held by the wafer chuck; and

a diffuser positioned within the nozzle, wherein the position of the diffuser within the nozzle is adjusted to adjust the removal rate profile of the stream of electrolyte applied by the nozzle.

15. The system of claim 14, further comprising:

a drive mechanism connected to the diffuser to adjust the position of the diffuser within the nozzle.

16. The system of claim 14, wherein the diffuser has a symmetric shape.

17. The system of claim 14, wherein the diffuser has an asymmetric shape.

18. The system of claim 17, wherein the tip of the nozzle has an asymmetric shape that aligns with the asymmetric shape of the diffuser when the diffuser is positioned at the tip of the nozzle.

19. A method of controlling removal rate uniformity during an electropolishing process in integrated circuit fabrication on a wafer, the method comprising:

applying a stream of electrolyte to different radial locations on the wafer using a nozzle positioned adjacent to the wafer;

applying a first electropolishing charge to a first electrode disposed adjacent to the edge of the wafer, wherein the first electrode applies the first electropolishing charge to the wafer;

applying a second electropolishing charge to a second electrode disposed adjacent to the first electrode, wherein the second electrode applies the second electropolishing charge to electrolyte that comes in contact with the second electrode as the electrolyte flows from the stream of electrolyte toward the edge of the wafer, and

wherein the second electrode is electrically isolated from the first electrode; and

adjusting the first electropolishing charge applied to the first electrode or the second electropolishing charge applied to the second electrode based on the radial location of the stream of electrolyte on the wafer,

wherein, when the stream of electrolyte is near the center of the wafer, the second electropolishing charge is greater than the first electropolishing charge.

20. The method of claim 19, wherein, when the stream of electrolyte is near the edge of the wafer, the second electropolishing charge is less than the first electropolishing charge; wherein the first electropolishing charge is greater when the stream of electrolyte is near the edge of the wafer than when the stream of electrolyte is near the center of the wafer; and wherein the second electropolishing charge is greater when the stream of electrolyte is near the center of the wafer than when the stream of electrolyte is near the edge of the wafer.

21. The method of claim 20, wherein, when the stream of electrolyte is near the edge of the wafer, the electropolishing current or voltage of the first electropolishing charge is adjusted based on a removal rate profile measured near the edge of a previous wafer that was electropolished.

22. The method of claim 19, wherein adjusting the first electropolishing charge applied to the first electrode or the second electropolishing charge applied to the second electrode based on the radial location of the stream of electrolyte on the wafer comprises:

when the stream of electrolyte is near the center of the wafer and far from the edge of the wafer:

opening a first switch between the first electrode and a power supply; and

closing a second switch between the second electrode and the power supply; and

when the stream of electrolyte is near the edge of the wafer:

closing the first switch; and

opening the second switch.

23. The method of claim 22, wherein the second electrode is partially encased in an insulator.

24. The method of claim 19, wherein adjusting the first electropolishing charge applied to the first electrode or the second electropolishing charge applied to the second electrode based on the radial location of the stream of electrolyte on the wafer comprises:

when the stream of electrolyte is near the center of the wafer and far from the edge of the wafer:

opening a first switch between the first electrode and a power supply; and

closing a second switch between the second electrode and the power supply;

when the stream of electrolyte is near the edge of the wafer:

closing the first switch; and

when the stream of electrolyte is at the edge of the wafer:

opening the second switch.

25. The method of claim 19, wherein adjusting the first electropolishing charge applied to the first electrode or the second electropolishing charge applied to the second electrode based on the radial location of the stream of electrolyte on the wafer comprises:

when the stream of electrolyte is near the center of the wafer and far from the edge of the wafer:

opening a switch between the first electrode and a first power supply; and

applying the second electropolishing charge to the second electrode using a second power supply; and

when the stream of electrolyte is near the edge of the wafer:

closing the switch;

applying the first electropolishing charge to the first electrode using the first power supply; and

adjusting the second electropolishing charge applied to the second electrode so that the second electropolishing charge is less than the first electropolishing charge.

26. The method of claim 19, wherein adjusting the first electropolishing charge applied to the first electrode or the second electropolishing charge applied to the second electrode based on the radial location of the stream of electrolyte on the wafer comprises:

when the stream of electrolyte is near the center of the wafer and far from the edge of the wafer:

applying the first electropolishing charge to the first electrode using a first power supply;

closing a switch between the second electrode and a second power supply;

applying the second electropolishing charge to the second electrode using the second power supply, wherein the second electropolishing charge is greater than the first electropolishing charge; and

when the stream of electrolyte is near the edge of the wafer:

opening the switch;

applying the first electropolishing charge to the first electrode using the first power supply, wherein the first electropolishing charge applied by the first power supply is greater when the stream of electrolyte is near the edge of the wafer than when the stream of electrolyte is near the center of the wafer.

27. The method of claim 19, wherein adjusting the first electropolishing charge applied to the first electrode or the second electropolishing charge applied to the second electrode based on the radial location of the stream of electrolyte on the wafer comprises:

when the stream of electrolyte is near the center of the wafer and far from the edge of the wafer:

applying the first electropolishing charge to the first electrode using a first power supply;

closing a switch between the second electrode and a second power supply;

applying the second electropolishing charge to the second electrode using the second power supply, wherein the second electropolishing charge applied by the second power supply is greater than the first electropolishing charge applied by the first power supply; and

when the stream of electrolyte is near the edge of the wafer:

adjusting the second electropolishing charge applied to the second electrode so that the second electropolishing charge is less than the first electropolishing charge; and

applying the first electropolishing charge to the first electrode using the first power supply, wherein the first electropolishing charge applied by the first power supply is greater when the stream of electrolyte is near the edge of the wafer than when the stream of electrolyte is near the center of the wafer.

28. The method of claim 19, wherein adjusting the first electropolishing charge applied to the first electrode or the second electropolishing charge applied to the second electrode based on the radial location of the stream of electrolyte on the wafer comprises:

when the stream of electrolyte is near the center of the wafer and far from the edge of the wafer:

opening a first switch between the first electrode and a power supply; and

closing a second switch between the second electrode and the power supply; and

when the stream of electrolyte is near the edge of the wafer:

closing the first switch; and

setting a resistor connected between the first switch and the power supply, wherein the resistor is set so that the second electropolishing charge is less than the first electropolishing charge.

29. The method of claim 19, wherein adjusting the first electropolishing charge applied to the first electrode or the second electropolishing charge applied to the second electrode based on the radial location of the stream of electrolyte on the wafer comprises:

when the stream of electrolyte is near the center of the wafer and far from the edge of the wafer:

opening a first switch between the first electrode and a power supply; and

closing a second switch between the second electrode and the power supply; and

when the stream of electrolyte is near the edge of the wafer:

closing the first switch; and

setting a resistor connected between the second switch and the power supply, wherein the resistor is set so that the second electropolishing charge is less than the first electropolishing charge.

30. The method of claim 19, wherein adjusting the first electropolishing charge applied to the first electrode or the second electropolishing charge applied to the second electrode based on the radial location of the stream of electrolyte on the wafer comprises:

when the stream of electrolyte is near the center of the wafer and far from the edge of the wafer:

setting a three-way resistor connected to the first and second electrodes and a power supply, wherein the three-way resistor is set to reduce the resistance between the second electrode and the power supply so that the second electropolishing charge applied to the second electrode is greater than the first electropolishing charge; and

when the stream of electrolyte is near the edge of the wafer:

setting the three-way resistor to reduce the resistance between the first electrode and the power supply so that the second electropolishing charge applied to the second electrode is less than the first electropolishing charge.

31. The method of claim 19, wherein adjusting the first electropolishing charge applied to the first electrode or the second electropolishing charge applied to the second electrode based on the radial location of the stream of electrolyte on the wafer comprises:

when the stream of electrolyte is near the center of the wafer and far from the edge of the wafer:

opening a first switch between the first electrode and a first power supply; and

closing a second switch between the second electrode and a second power supply; and

when the stream of electrolyte is near the edge of the wafer:

closing the first switch; and

adjusting the first electropolishing charge applied by the first power supply and the second electropolishing charge applied by the second power supply so that the second electropolishing charge is less than the first electropolishing charge.

32. A system for controlling removal rate uniformity during an electropolishing process in integrated circuit fabrication on a wafer, the system comprising:

a wafer chuck configured to hold and position the wafer during the electropolishing process;

a nozzle configured to apply a stream of electrolyte to the wafer,

wherein the stream of electrolyte is applied to different radial locations on the wafer;

a first electrode configured to be adjacent to an edge of the wafer when the wafer is held in the wafer chuck,

wherein, during the electropolishing process, a first electropolishing charge is applied to the first electrode, and the first electrode applies the first electropolishing charge to the wafer;

a second electrode disposed adjacent to the first electrode,

wherein, during the electropolishing process, a second electropolishing charge is applied to the second electrode, and the second electrode applies the second electropolishing charge to the electrolyte that comes in contact with the second electrode as the electrolyte flows from the stream of electrolyte toward the edge of the wafer, and

wherein the second electrode is electrically isolated from the first electrode; and

a control circuit configured to adjust the first electropolishing charge applied to the first electrode or the second electropolishing charge applied to the second electrode based on the radial location of the stream of electrolyte on the wafer,

wherein, when the stream of electrolyte is near the center of the wafer, the second electropolishing charge is greater than the first electropolishing charge.

33. The system of claim 32, wherein the control circuit comprises:

a first switch connected between the first electrode and a power supply; and

a second switch connected between the second electrode and the power supply,

wherein, when the stream of electrolyte is near the center of the wafer and far from the edge of the wafer:

the first switch is open, and

the second switch is closed, and

wherein, when the stream of electrolyte is near the edge of the wafer:

the first switch is closed, and

the second switch is open.

34. The system of claim 33, wherein the second electrode is partially encased in an insulator.

35. The system of claim 32, wherein the control circuit comprises:

a first switch connected between the first electrode and a power supply; and

a second switch connected between the second electrode and the power supply,

wherein, when the stream of electrolyte is near the center of the wafer and far from the edge of the wafer:

the first switch is open, and

the second switch is closed,

wherein, when the stream of electrolyte is near the edge of the wafer:

the first switch is closed, and

wherein, when the stream of electrolyte is at the edge of the wafer:

the second switch is open.

36. The system of claim 32, wherein the control circuit comprises:

a switch connected between the first electrode and a first power supply; and

a second power supply connected to the second electrode,

wherein, when the stream of electrolyte is near the center of the wafer and far from the edge of the wafer:

the switch is open, and

the second power supply applies the second electropolishing charge to the second electrode, and

wherein, when the stream of electrolyte is near the edge of the wafer:

the switch is closed, and

the first power supply applies the first electropolishing charge to the first electrode, and

the second electropolishing charge is adjusted so that the second electropolishing charge is less than the first electropolishing charge.

37. The system of claim 32, wherein the control circuit comprises:

a first power supply connected to the first electrode;

a switch connected between the second electrode and a second power supply,

wherein, when the stream of electrolyte is near the center of the wafer and far from the edge of the wafer:

the first power supply applies the first electropolishing charge to the first electrode,

the switch is closed, and

the second power supply applies the second electropolishing charge to the second electrode, wherein the second electropolishing charge is greater than the first electropolishing charge, and

wherein, when the stream of electrolyte is near the edge of the wafer:

the switch is open, and

the first power supply applies the first electropolishing charge to the first electrode, wherein the first electropolishing charge applied by the first power supply is greater when the stream of electrolyte is near the edge of the wafer than when the stream of electrolyte is near the center of the wafer.

38. The system of claim 32, wherein the control circuit comprises:

a first power supply connected to the first electrode;

a switch connected between the second electrode and a second power supply,

wherein, when the stream of electrolyte is near the center of the wafer and far from the edge of the wafer:

the first power supply applies the first electropolishing charge to the first electrode,

the switch is closed, and

the second power supply applies the second electropolishing charge to the second electrode, wherein the second electropolishing charge applied by the second power supply is greater than the first electropolishing charge applied by the first power supply, and

wherein, when the stream of electrolyte is near the edge of the wafer:

the second electropolishing charge applied to the second electrode is adjusted so that the second electropolishing charge is less than the first electropolishing charge, and

the first power supply applies the first electropolishing charge to the first electrode, wherein the first electropolishing charge applied by the first power supply is greater when the stream of electrolyte is near the edge of the wafer than when the stream of electrolyte is near the center of the wafer.

39. The system of claim 32, wherein the control circuit comprises:

a first switch connected between the first electrode and a power supply;

a second switch connected between the second electrode and the power supply; and

a resistor connected between the first switch and the power supply,

wherein, when the stream of electrolyte is near the center of the wafer and far from the edge of the wafer:

the first switch is open, and

the second switch is closed, and

wherein, when the stream of electrolyte is near the edge of the wafer:

the first switch is closed, and

the resistor is set so that the second electropolishing charge is less than the first electropolishing charge.

40. The system of claim 32, wherein the control circuit comprises:

a first switch connected between the first electrode and a power supply;

a second switch connected between the second electrode and the power supply; and

a resistor connected between the second switch and the power supply,

wherein, when the stream of electrolyte is near the center of the wafer and far from the edge of the wafer:

the first switch is open, and

the second switch is closed, and

wherein, when the stream of electrolyte is near the edge of the wafer:

the first switch is closed, and

the resistor is set so that the second electropolishing charge is less than the first electropolishing charge.

41. The system of claim 32, wherein the control circuit comprises:

a three-way resistor connected to the first and second electrodes and a power supply,

wherein, when the stream of electrolyte is near the center of the wafer and far from the edge of the wafer:

the three-way resistor is set to reduce the resistance between the second electrode and the power supply so that the second electropolishing charge applied to the second electrode is greater than the first electropolishing charge, and

wherein, when the stream of electrolyte is near the edge of the wafer:

the three-way resistor is set to reduce the resistance between the first electrode and the power supply so that the second electropolishing charge applied to the second electrode is less than the first electropolishing charge.

42. The system of claim 32, wherein the control circuit comprises:

a first switch connected between the first electrode and a first power supply;

a second switch connected between the second electrode and a second power supply,

wherein, when the stream of electrolyte is near the center of the wafer and far from the edge of the wafer:

the first switch is open, and

the second switch is closed, and

wherein, when the stream of electrolyte is near the edge of the wafer:

the first switch is closed, and

the first electropolishing charge applied by the first power supply and the second electropolishing charge applied by the second power supply are adjusted so that the second electropolishing charge is less than the first electropolishing charge.

43. The system of claim 32, wherein the wafer chuck, the first electrode, and the second electrode are components of a chuck assembly, and wherein the chuck assembly further comprises:

an electrical contact assembly having a lower contact;

a shaft assembly having:

a lower contact ring, wherein the lower contact ring makes electrical contact with the lower contact of the electrical contact assembly, and

a shaft electrically connected to the lower contact ring;

a top assembly having:

a block, wherein the block makes electrical contact with the shaft,

a metal plate electrically connected to the block, and

leaf spring contacts electrically connected to the metal plate;

a bottom assembly having a wafer-centering ring, wherein the wafer-centering ring makes electrical contact with the leaf spring contacts, and wherein the wafer-centering ring is electrically connected to the first electrode.

44. The system of claim 43, wherein:

the electrical contact assembly has an upper contact;

the shaft assembly has:

an upper contact ring, wherein the upper contact ring makes electrical contact with the upper contact of the electrical contact assembly,

a contact pin electrically connected to the upper contact ring,

a contact rod electrically connected to the contact pin, and

a spring contact electrically connected to the contact rod; and

the top assembly has:

a contact screw, wherein the contact screw makes electrical contact with the spring contact,

a contact nut electrically connected to the contact screw,

wires electrically connected to the contact nut,

top plate inserts electrically connected to the wires,

compression springs, wherein the compression springs make electrical contact with the top plate inserts, and

pins, wherein the pins make electrical contact with the compression springs, and wherein the compression springs and the pins make electrical contact with the second electrode.